Abstract prepared for submittal to the 6th International Workshop on the Physics of Compressible Turbulent Mixing, June 18-21, 1997, Marseille-France

Nova experiments to investigate hydrodynamic instabilities in the solid state*

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We are conducting experiments on the Nova laser to investigate the Rayleigh-Taylor (RT) instability in metal foils maintained in the solid state. The RT dispersion curve is predicted to be very sensitive to the state of the material, with perturbation growth greatly reduced in the solid state compared to the liquid state,[1,2] but data are sparse[2,3]. We will describe experiments conducted to investigate the RT instability in metal foils such as Cu and Mo at compressions of 1.5-2.0, pressures of 3-5 Mbar, and temperatures on either side of the melt point.

We conduct our experiment in indirect-drive, where the laser energy is converted to a thermal x-ray drive in a hohlraum (radiation cavity). The planar targets consist of 20 μm of CH(Br) ablator backed by 15 μm of Cu, with sinusoidal ripples at the interface, and are mounted on the wall of the hohlraum. To reach multi-Mbar pressures while maintaining the foils in the solid state requires a nearly adiabatic compression in the absence of preheat. To achieve this, we have developed a Planckian drive with a radiation temperature T_r of ~30 eV in the foot with a nearly linear rise in T_r over 6 ns to a peak of 90-100 eV. Since $P_{Laser} \propto T_r^{3.5}$, this peak/foot factor of 3 in T_r corresponds to roughly 50:1 contrast in the laser pulse. Preheat shields inside the hohlraum prevent the target from seeing any hard x-rays. Simulations of our lowest adiabat drive give a peak pressure of 3 Mbar, compression of 1.5-2.0, and temperatures $T \leq 0.3$ eV < T_{melt}. The ripple at the CH(Br)-Cu interface typically corresponds to side-by-side sinusoids of wavelengths λ_1=20 μm and λ_2=50 μm, thus yielding crude dispersion curve information on every shot. For our low adiabat drives, we observe RT growth of the perturbations only late in time, t > 10 ns, after the drive has turned off and the foil is decompressing. The observed growth is significantly delayed relative to when "classical" simulations (that is, simulations neglecting material strength effects) predict growth should commence. High adiabat drives of similar targets lead to prompt RT growth, in agreement with classical simulations. We interpret our results within the context of a solid-state RT dispersion curve analysis, and with simulations including material strength effects.[3,4]

We will also present results from dynamic Bragg diffraction measurements to investigate lattice response of single crystal solids to compression.[5] We plan to use such measurements to (1) verify that our accelerated metal foils are still in the solid state while under compression (melt would imply no lattice and hence no Bragg peak), and (2) infer the foil compression from the decreased lattice spacing.

*Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

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